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Mapping the Structure and Evolution of Titan's Northern Polar Vortex

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Abstract

Titan is the largest moon of Saturn and is host to a thick, Nitrogen dominated atmosphere. With an obliquity of 27°, strong seasonal variations are seen in Titan's atmospheric temperature and composition. Cold winter temperatures lead to the formation of a polar vortex, much like those observed on the terrestrial planets. Titan's polar vortex is characterized by cold stratospheric temperatures and increased trace gas abundance, which subside deep into the stratosphere from the upper atmosphere where they are created by complex photo-chemistry (1). Many previous studies have investigated the latitudinal variations in temperature and gas abundance (2, 3, 4), but no significant longitudinal studies have yet been performed. Here we present the first comprehensive study of the zonal variations of Titan's northern polar vortex. We use a 13-year dataset of infra-red spectra measured by Cassini's CIRS instrument and the NEMESIS radiative transfer retrieval tool to search for zonal asymmetries in the temperature and trace gas distributions. Searching for asymmetry, or structure, in the vortex allows us to better understand the complex dynamics and atmospheric processes which govern its evolution. Comparison with the vortices of Earth, Mars and Venus also provide insight into how the vortex evolution varies between planets. Our results show that Titan's northern vortex appears to have no significant asymmetry throughout its lifetime, instead growing and shrinking uniformly, a behaviour not seen in any other planetary vortex.

1. Observations

CIRS observations span over 13 years, from 2004 through to 2017 with 127 targeted flybys of Titan. This provides the opportunity to study Titan's atmosphere over approximately half a Titan year, enough to observe seasonal variations. CIRS covers the spectral range 10-1400cm^{-1} with an adjustable resolution of 0.5-15 cm^{-1}. For this study, only observations which cover the northern polar region are needed. 18 fly-bys are selected using a resolution of 2.5cm^{-1}, which provides the necessary spatial resolution to map the northern hemisphere and also resolve individual gas peaks. Selected flybys range from northern winter (L_s = 326.95°) through to northern summer (L_s = 85.33°).

2. Method

We use the radiative transfer retrieval tool, NEMESIS, to invert infrared CIRS spectra to obtain temperature profiles and abundances of HC3N, HCN and C4H2. NEMESIS uses a correlated-k approximation method and a non-linear inversion method (5). We then investigate the zonal variations in retrieved properties to determine the changes in evolution of the vortex throughout our dataset.

3. Results

Figure 1 shows the degree of asymmetry present in the vortex temperature distributions at three pressure levels, over all selected flybys. The vortex is not seen to exhibit any significant temperature asymmetry at any point throughout the dataset. Early fly-bys (late winter) show the most variations, as the vortex is strongest. By the end of the mission there appears to be no variations at all, as expected as the vortex is severely weakened by then. Figure 2 shows the asymmetry present in the vortex composition, for C_4H_2, HC_3N and HCN gas abundances. Similar to the temperature distributions, there appears to be no significant zonal variations in the composition of the vortex. Some level of asymmetry can be seen in the early fly-bys when the vortex remains enriched, although it does not pass the 3-sigma level and so is not deemed significant. By the end of the mission there is very little asymmetry, as the vortex trace gas abundances are greatly depleted.

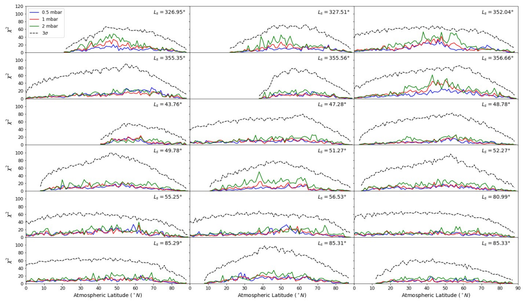

Figure 1: Temperature Asymmetry plots for all selected flybys. Values are never seen to surpass the 3-sigma boundary at any point at 0.5, 1 or 5mbar, suggesting the vortex remains symmetric in temperature distributions.

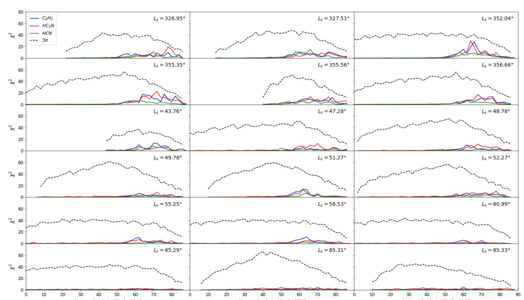

Figure 2: Composition Asymmetry plots for all selected flybys. Similar to Figure 1, gas abundance distributions in the vortex for C_4H_2, HC_3N and HCN are never seen to surpass 3-sigma boundary, suggesting vortex also remains symmetric in composition.

4. Discussion

The results show that Titan's northern vortex appears to remain zonally-uniform in both its temperature and composition as it evolves from a strong well developed vortex in the northern winter, through to its breakup in the northern summer. These results suggest that the vortex grows and shrinks uniformly throughout its lifetime. Comparison with the vortices of Earth, Mars and Venus will help understand what processes lead to this result, as the polar vortices present on all three have been observed to be highly asymmetric for different reasons (6, 7). These comparisons will help better understand what wave processes and dynamical relationships drive the evolution and breakup of Titan's northern vortex, and can aid future GCMs in attempting to replicate Titan's complex circulation.

Acknowledgements

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References

[1] Wilson. E. H. and Atreya. S. K.: Current state of modeling the photochemistry of Titan's mutually dependant atmosphere and ionosphere, Journal of Geophysical Research (Planets), 109:E06002, Jun 2004

[2] Teanby. N. A., et al.: Titan''s winter polar vortex structure revealed by chemical tracers, Journal of Geophysical Research (Planets), 113:E12003, Dec 2008

[3] Vinatier. S.: Seasonal variations in Titan's middle atmosphere during the northern spring derived from Cassini/CIRS observations, Icarus, 250:95-115, Apr 2015

[4] Sylvestre. M., et al.: Seasonal evolution of C2N2, C3H4 and C4H2 abundances in Titan's lower stratosphere, Astronomy and Astrophysics, 609:A64, Jan 2018

[5] Irwin. P. G. J., et al.: The NEMESIS planetary atmosphere radiative transfer and retrieval tool, Journal of Quantitative Spectroscopy and Radiative Transfer, 109:1136-1150, Apr 2008

[6] Waugh. D. W. and Randel. W. J.: Climatology of Arctic and Antarctic Polar vortices using Elliptical Diagnostics, Journal of the Atmospheric Sciences, 56, 1594-1613

[7] Mitchell. D. M, et al.: Polar vortices on Earth and Mars: A comparative study of the climatology and variability from reanalyses, Quarterly Journal of the Royal Meteorological Society, 141, 687, 550-562.